Recruitment and Distribution of Postlarval and Early Juvenile Penaeid Shrimp in a Large Mangrove Estuary in the Gulf of Guayaquil During 1985

Reclutamiento y Distribución de Postlarvas y Juveniles de Camarones Peneidos en un Estuario Grande de Manglares en el Golfo de Guayaquil durante 1985.

Roger J. Zimmerman y Thomas J. Minello

Resumen

El estudio se refiere a los patrones de distribución y abundancia de camarones Penaeus en cinco esteros (Data, Morro, Corvinero, Grande y Salado) en el Estuario del Río Guayas, todos ellos dominados por habitat de manglar y donde es evidente el gradiente salino. El período del estudio comprende desde febrero de 1985 hasta enero de 1986.

Los extremos de la temperatura del agua fueron: 31°C en febrero y marzo (estación lluviosa) y 24°C en julio y agosto (estación seca). La salinidad, en contraste, varió más que la temperatura y una relativa alta salinidad durante 1985 fue indicación de un año seco. El gradiente ambiental en el estuario fue evidente: bajas salinidades en el Estero Salado, en la cabeza del estuario, y altas salinidades en el Estero del Morro y Golfo de Gauyaquil. Dentro de los esteros, las menores salinidades correspondieron a los lugares interiores con ingreso de aguas dulces (Esteros Salado y Corvinero) y las salinidades más altas debidas a la evaporación tambien estuvieron en lugares interiores de los esteros más próximos a la costa (Esteros Morro y Data).

Las tallas de las postlarvas (pls) y juveniles obtenidas en los esteros estuvieron entre 5 mm y 70 mm de longitud total (rostro-telson) y el orden de abundancia fue: (1) Penaeus californiensis, (2) P. vannamei, (3) P. stylirostris y (4) P. occidentalis. El primero fue nueve veces más abundante que los demás.

El patrón de abundancia estacional indicó que P. californiensis fue numeroso todo el año, con máximos en febrero (1985) y enero (1986). P. vannamei tambien estuvo presente todo el año en los muestreos, pero fue menos abundante y sus picos correspondieron a julio, septiembre y enero. P. stylirostris, también escaso, presento su mayor abundancia en las muestras de marzo y noviembre. Por otra parte, los patrones de abundancia indicaron que los esteros más cercanos a la fuente de reclutamiento (Golfo de Guayaquil) ofrecen un habitat para un mayor número de camarones por unidad de área, que aquellos esteros más alejados. Así, el mayor número para todas las especies estuvo en la boca del Estero del Morro. Los esteros Corvinero, Salado y Grande, en la parte interior, tuvieron sustancialmente menor abundancia. También, la mayor abundancia de camarones se esc ontró en los lugares con manglar, al interior, mientras que en los lugares de aguas abiertas, en la mitad de los esteros, la abundancia fue menor.

La distribución estacional de los parámetros ambientales sugieren que una mayor abundancia de P. californiensis se relaciona con altas salinidades, mientras que la menor abundancia de las otras especies implican lo contrario.

Los datos de 1985 indican que un año seco y frío parece afectar negativamente el reclutamiento y la distribución de P. vannamei y de P. stylirostris. Sin embargo, todas las especies respondieron con incrementos durante la estación lluviosa, demostrando que las condiciones meteorológicas ayudan a regular la época y el tamaño de los eventos de reclutamiento.

Es importante reconocer que las tres especies utilizaron las áreas interiores de los esteros como criaderos primarios. Las muestras indican que todas las especies fueron atraídas al interior de las áreas dominadas por manglares y, en consecuencia, sirvieron como habitat de cría primario para las tres especies en referencia.

Introduction

The general relationship between area of intertidal vegetation and commercial yield of shrimp has been reported by Turner (1977). Since this relationship extends to the tropics (Martosubroto and Naamin, 1977; Jothy, 1984), understanding the nursery role of intertidal mangrove habitat for shrimp may be important in management of tropical estuaries (Garcia and le Reste, 1981; Turner, this publication).

The life cycle of most penaeid shrimp begins with offshore spawning and continues through a series of planktonic larval stages that terminate with postlarvae carried into estuaries by tidal currents (Staples and Vance, 1985). Once in the estuarine environment, juvenile shrimp find ideal nursery conditions for growth and survival. Vegetation in estuaries offers young shrimp a protective structure that is effective against predatory fishes (Minello and Zimmerman, 1984) and substrate that encourages development of epibenthic plant and animal foods (Gleason and Zimmerman, 1984; Leber, 1985). Estuarine bottom without vegetation is also valuable and deters predation with sediments favorable for shrimp burrowing and turbid water that obstructs predator vision (Minello et al., 1987). Nonvegetated muddy bottom may also provide large numbers of infaunal worms on which shrimp feed (Flint, 1985).

The variety of useful estuarine habitats allow various shrimp species to select different microhabitats (Zimmerman and Minello, 1984). Accordingly, one species may select mangrove habitat while another thrives in intertidal mud flats. The suitability of different habitats for meeting preferences of young shrimp will vary along environmental gradients and through interannual variability. For example, annual changes can shift habitat-related abundances of shrimp foods, such as phytoplankton, epiphytic algae, epifauna, infauna, and detritus, thus favoring one or another shrimp species according to dietary preferences. Likewise, mangrove habitat in brackish water at the head of an estuary is likely to provide different resources than mangrove habitat in marine water at the mouth of an estuary. Congeneric species of shrimp may exploit these separately because they use the estuary differently.

In the Ecuadorian estuary formed between the Guayas River and the Gulf of Guayaquil, environmental variability is an important feature (Stevenson, 1981). This large estuary is located in northwestern tropical South America in a transitional position between humid Colombia and arid Peru (Cruz-Orozco, 1984). Rainfall is highly seasonal and varies annually dependent upon the position of cold water currents offshore (Cucalon, 1983). Normally, the cold water offshore has a drying influence, but when currents are deflected, such as during El Nino events, high rainfall occurs. Rainfall and commercial yield of shrimps in Ecuador appear to be positively correlated (McPadden, 1985; Klima, this publication); yet the relationship between rainfall and utilization of nursery habitats by shrimp in the Guayas Estuary is not clearly understood.

The aim of current research is to characterize habitat utilization and resource partitioning among shrimp species in the Guayas Estuary. In the long-term, the program is designed to compare effects of wet and dry years between habitats with and without vegetation. An initial study is presented here, addressing shrimp distributions in the estuary during 1985, a dry year.

Methods

Objectives

The first objective was to relate distribution and abundance patterns among Penaeus species in the Guayas Estuary to seasonal rainfall and salinity characteristics. The second objective was to demonstrate that juveniles of some shrimp species are attracted to mangrove habitats.

Study Sites and Design

The study was designed to survey five large branches (esteros) of the estuary along an environmental gradient beginning at the outskirts of the city of Guayaquil and extending 50 kilometers to Morro Point at the Gulf of Guayaquil. Within each estero, sampling sites were stratified to represent (1) the mangrove interior, (2) the area in the middle of the estero, and (3) the area just outside the entrance to the estero. All of the esteros were dominated by mangrove habitat that became more extensive toward the interior. Within the main estuary, a salinity gradient was evident from where the Guayas River entered at the head of the estuary, extending to the mouth and marine conditions at the Gulf of Guayaquil. The esteros studied along this gradient were Estero Data, Estero Morro, Estero Corvinero, Estero Grande, and Estero Salado (Figure 1).

Within esteros, the selection of sampling sites was designed to assess shrimp distributions and abundances related to nearness of mangroves. Accordingly, the interior sites were located in extensive mangrove areas at the head of each estero. By comparison, the other sites were removed from mangrove dominance. Outer sites were at the entrances to esteros where shorelines consisted mostly of sandy beaches. Middle sites were just inside the esteros where wide channels formed large bodies of open water. The middle sites were located inside along the wide channels comprising the main body of open water in the esteros.

Sampling

Sampling during the first year began in February 1985 and continued through January 1986. Samples were taken using a one-meter wide beam trawl with a 500 micron mesh (Renfro, 1963) during the highest tides of each month. Three replicate tows were obtained from each of the three sites within each estero. The beam trawl was pulled by hand over a distance of 33 meters on the bottom for each of the three replicates. Thus, the total distance at each site was about 100 meters, and since the trawl was one meter wide, the area covered was also equivalent to the distance towed. The trawl was deployed from the stern of a small boat while the boat moved slowly forward into the current and a line attached to the trawl was paid out. At the end of the line the boat was held in position while the trawl was slowly pulled in by hand into the current. On deck the sample was washed free of mud then removed and placed in a container with 10 percent formaldehyde in seawater for preservation. Shrimp and other organisms were removed and measured during laboratory processing of the samples. Penaeid shrimp were identified according to Loesch and Avila (1965) and Yoong and Reinoso (1983) and measured in millimeters from the tip of rostrum to the tip of telson (total length). Other organisms were identified using local taxonomic keys. Data were entered onto an IBM System 36 computer file for analyses.

Results

Physical Conditions

Temperature: Water temperature extremes ranged from a high of 31oC in February and March (wet season) to a low of 24oC in July and August (dry season). Mean temperatures throughout the estuary were moderate during every month (Figure 2) suggesting only minor influences on shrimp activity.

Salinity: By contrast, salinity was more variable than temperature. Conditions during 1985 were dominated by low rainfall (Figure 3), and the relatively high salinities throughout 1985 were indicative of the dry year. The monthly changes in salinity (Figure 2) reflected the duration and intensity of the wet and dry seasons.

The Environmental Gradient: An environmental gradient in the estuary was evident as reflected by low salinities in Estero Salado, at the head of the estuary, and high salinities in Estero Morro, at the Gulf of Guayaquil. Within the esteros, the lowest salinities were at the interior sites of upper esteros, where freshwater entered (Estero Salado and Estero Corvinero), and the highest salinities due to evaporation, were also at interior sites, in these instances at esteros nearest the coast (Estero Morro and Estero Data). Temperatures, as previously noted, did not differ between esteros or among sites, although interior sites were the most variable. Along the estuarine gradient, the ratio of mangrove to open-water area was greatest in the upper estuary and diminished toward the coast where intertidal mudflats, sandy beaches and subtidal habitats prevailed.

Shrimp Sizes

Sizes of postlarvae and juvenile shrimp taken in the esteros were between 5 mm and 70 mm total length (measured from the tip of the rostrum to the end of the telson). Mostly, they were small with monthly mean sizes ranging between 12 mm and 20 mm total length for P. californiensis, and between 12 mm and 37 mm total length for P. vannamei, the two most abundant species. Overall, mean sizes of P. vannamei were greater than P. californiensis.

Shrimp Abundance Patterns

Overall abundances among species: Rank order of abundance in the estuary among Penaeus during 1985 was: (1) Penaeus californiensis, (2) P. vannamei, (3) P. stylirostris, and (4) P. occidentalis. The dominant species, Penaeus californiensis (overall mean = 9.07 per sample), was roughly nine times more abundant than all other shrimp species (Figure 4).

Seasonal abundance patterns: P. californiensis were numerous throughout the year, with peaks in February 1985 and January 1986 (Figure 5). P. vannamei were also present throughout the year, but much less abundant with minor peaks during July, September and January (Figure 5). P. stylirostris were also few in number and had highest abundances in March and November samples (Figure 5).

Abundance patterns among esteros: Our results show that esteros closest to the recruitment source (the Gulf of Guayaquil) provide nursery habitat for more shrimp per unit area than those farther away. Accordingly, the largest numbers for all shrimp species were located at the mouth of the estuary in Estero Morro (Figure 4). The remaining esteros in the estuary were roughly similar in overall abundances. As might be expected, Estero Morro had the highest numbers of the two most abundant shrimps, Penaeus californiensis (18.48 per sample) and P. vannamei (1.37 per sample). Estero Data was outside of the main estuary with its mouth opening directly into the Gulf of Guayaquil. This estero had abundances of Penaeus vannamei (1.16 per sample) similar to those in Estero Morro, but abundances of P. californiensis (5.98 per sample) were lower. Esteros Corvinero, Salado and Grande, inside the main estuary, had substantially lower abundances of P. vannamei and P. stylirostris. The number of P. occidentalis were too low during 1985 to establish a pattern. P. brevirostris did not occur in the samples.

Abundance patterns among sites: Shrimp abundance was highest at interior mangrove sites, with lowest abundances at the open-water sites in the middle of esteros. P. californiensis were the most numerous at interior sites and at the entrances to esteros (10.24 and 10.91 per sample, respectively; Figure 6) and fewest in the middle estero sites (5.48 per sample; Figure 6). By comparison, P. vannamei and P. stylirostris were most abundant at interior sites (1.42 per sample; Figure 6) and least abundant at middle and entrance sites (0.40 and 0.31 per sample, respectively; Figure 6).

Interspecies Relationships

Penaeus californiensis was the most abundant shrimp followed distantly by P. vannamei and P. stylirostris (Figures 4 and 5). Penaeus vannamei and P. stylrostris were similar in number and abundance pattern. Both species were present throughout the year, but at low densities. In each, increases in numbers occurred in short-term pulses. P. californiensis on the other hand, was more uniformly present in high numbers throughout the year.

The two most abundant species, P. californiensis and P. vannamei, responded during the wet season with peaks in abundance (Figure 5). All species were more abundant in the esteros nearest the Gulf of Guayaquil (Estero Morro and Estero Data) and less abundant within the upper main estuary (Esteros Corvinero, Grande and Salado). Penaeus occidentalis was notably rare in most of our samples and, like P. brevirostris, apparently did not use the nursery habitats sampled the same as the other species.

Abundances Relative to Temperature and Salinity

Seasonal temperatures and salinities followed an inverse relationship (Figure 2), with lowest salinities and highest temperatures occurring in wet season months of February, March and April. Lowest temperatures corresponded to highest salinities in dry season months of July, August and September. As stated before, the predominance of relatively high salinities in the estuary reflected the fact that 1985 was a dry year. The high abundances of P. californeinsis suggest a relationship to the relatively high salinities, while low abundances of the other species imply the opposite. This observation is supported by a change during high rainfall periods in January and February of 1986, when P. vannamei became the most abundant species in the esteros near the coast. This change and the overall low numbers of P. vannamei and P. stylirostris during 1985, suggests a strong dependence on rainfall and warm season conditions by these two species. By contrast, high rainfall may be relatively less important and very low salinities may even be detrimental to abundances of P. californiensis.

Discussion

Influence of the Physical Environment

Our data from 1985 indicate a cool dry year that appears to have adversely affected recruitment and distribution of two shrimp species in the estuary. This was reflected by the low abundances of P. vannamei and P. stylirostris throughout the 1985 wet and dry seasons. However, all species responded to some extent with increases during the wet season and this relationship demonstrates that meteorological conditions help to regulate the timing and size of recruitment events. The size of recruitment, in turn, appears to affect extensiveness of distribution. Since annual variability can be expected (including dry years as well as wet El Nino years), corresponding changes in numbers and distributions among these shrimp species are likely.

The effect of meteorological patterns is less evident in P. californiensis although dry conditions during 1985 appeared to favor this species. The dominance of P. californiensis may have to do with lack of congeneric species competition, increased food, favorable transport and dispersion of postlarvae or any number of causes not currently understood. The relationship to marine conditions is also supported by data from Loesch and Avila (1966) who reported dominance of P. californiensis in the estuary during drought years of 1962 and 1963.

A long-term program is needed to address relationships between nursery recruitment (abundances of postlarvae and early juveniles) and annual changes in temperature and rainfall. A program is especially needed to determine causal mechanisms within selected nurseries that control specific habitat characteristics for shrimp as they relate to physical conditions.

Habitat Selection Within the Nursery

Among the most numerous shrimp species from our samples, all were attracted to the interior areas dominated by mangroves (Figure 6). Accordingly, these mangrove rich areas served as primary nursery habitat for P. californiensis, P. vannamei and P. stylirostris. Inside the esteros, all postlarvae apparently moved rapidly to the interior mangrove nursery. One difference was the relatively high numbers of P. californiensis at the entrances to the esteros which suggests ecological separation between this species and the others. Differences in shrimp abundances were also evident between esteros at the head of the main estuary containing fewer shrimp per unit area (Corvinero, Salado and Grande) and esteros at the mouth of the main estuary with more shrimp per unit area (Data and Morro). This density gradient may have been due to the relatively small shrimp recruitment during 1985. Regardless of the cause, distance from the recruitment source (the Gulf of Guayaquil) appeared to be a significant factor in determining the number of young, especially for P. vannamei and P. stylirostis, in an estero.

It is important to recognize that three shrimp species utilized the interior areas within esteros as primary nurseries. This raises the possibility of relatively fine-scale habitat resource and selection by these species. Moreover, selection for the mangrove nursery implies habitat requirements that may differ from the other shrimp species, P. brevirostris and P. occidentalis, in Ecuadorian fisheries. Our data indicate that mangroves in the Guayas Estuary do not serve as a nursery for these two species.

Investigations addressing habitat-specific utilization differences among species within the Guayas Estuary are needed. Abundance differences between shrimp species occupying habitats, including intertidal mangrove, intertidal mud flats, and various subtidal bottoms without vegetation, could reveal further important habitat selection. Our data indicates habitat selection and such nursery habitats may be irreplaceable. In other regions, differences in selection of nursery habitat by shrimp have been demonstrated, such as between seagrasses and mangroves in Australia (Staples et al., 1985) and marsh and mud bottom in Texas (Zimmerman and Minello, 1984). These studies show that a variety of habitats in an estuary may have nursery value, depending on the shrimp. Differences between species in feeding habits, interactions with predators and with the physical environment easily account for habitat selection differences. Importantly, the Guayas estuary has ten commercially important penaeids (McPadden, 1985) and, for most of these, nursery habitats have yet to be identified.

Consequences of the Postlarval Fishery

A postlarval fishery for pond stocking exploits every estero in Ecuador. An estimated 90,000 fishermen are involved in this fishery during monthly high tides (MacPadden, 1985). The variety of methods used by these fishermen has not been documented, and the effects of their fishing on reduction and structuring of recruitment in the nursery are not known. Our information suggests that P. vannamei and P. stylirostris are selectively taken by fishermen and P. californiensis is selectively excluded. The impact of such differential exploitation could have a long-term restructuring effect on the overall shrimp population.

Further studies to evaluate the effect of the postlarval fishery are recommended. The program should compare various methods used by fishermen and test the potential of each for changing species distribution and population structure.

Summary

Mangrove areas in the Guayas estuary are extensively used as nurseries by at least three commercially important Penaeus species. Of these, P. vannaemi and P. stylirostris were closely associated with mangroves and P. californiensis was more generally distributed. The esteros nearest the coast had highest shrimp densities and numbers diminished toward the head of the estuary.

Conditions during 1985 were dominated by below average rainfall and higher salinities that apparently favored increased abundances of P. californiensis. By contrast, P. vannaemi and P. stylirostris were adversely affected by low rainfall as reflected by low abundances. During early 1986, P. vannaemi responded to increased rainfall with markedly greater abundances. Since the target species for pond stocking is P. vannaemi, and P. californiensis is considered an inferior mariculture shrimp, these relationships have a dramatic effect on Ecuador's shrimp industry. During wet years, P. vannaemi postlarvae are abundant and the industry thrives; during dry years, such as in 1985, desirable postlarvae are scarce and the industry suffers.

Surprisingly, the offshore shrimp fishery does not correspond to relative abundances of juveniles in the Guayas mangrove nursery. The most abundant shrimp in offshore catches is P. occidentalis which is among the least abundant in association with mangroves. The nursery is either in another region or in another habitat within one estuary. In any case, the nursery for P. occidentalis has not been identified. In opposite manner, P. californiensis is among the most numerous of shrimp using the Guayas estuary and its abundance is not reflected in offshore catches. We concur with Klima (this publication) that this species is under-exploited due to poor definition of adult fishing grounds. Both of these subjects, characterization of the P. occidentalis nursery and identification of the P. californiensis adult grounds, are useful areas for future research.

Figure 1. Sampling sites in branches (esteros) of a large estuary near Guayaquil, Ecuador during 1985.

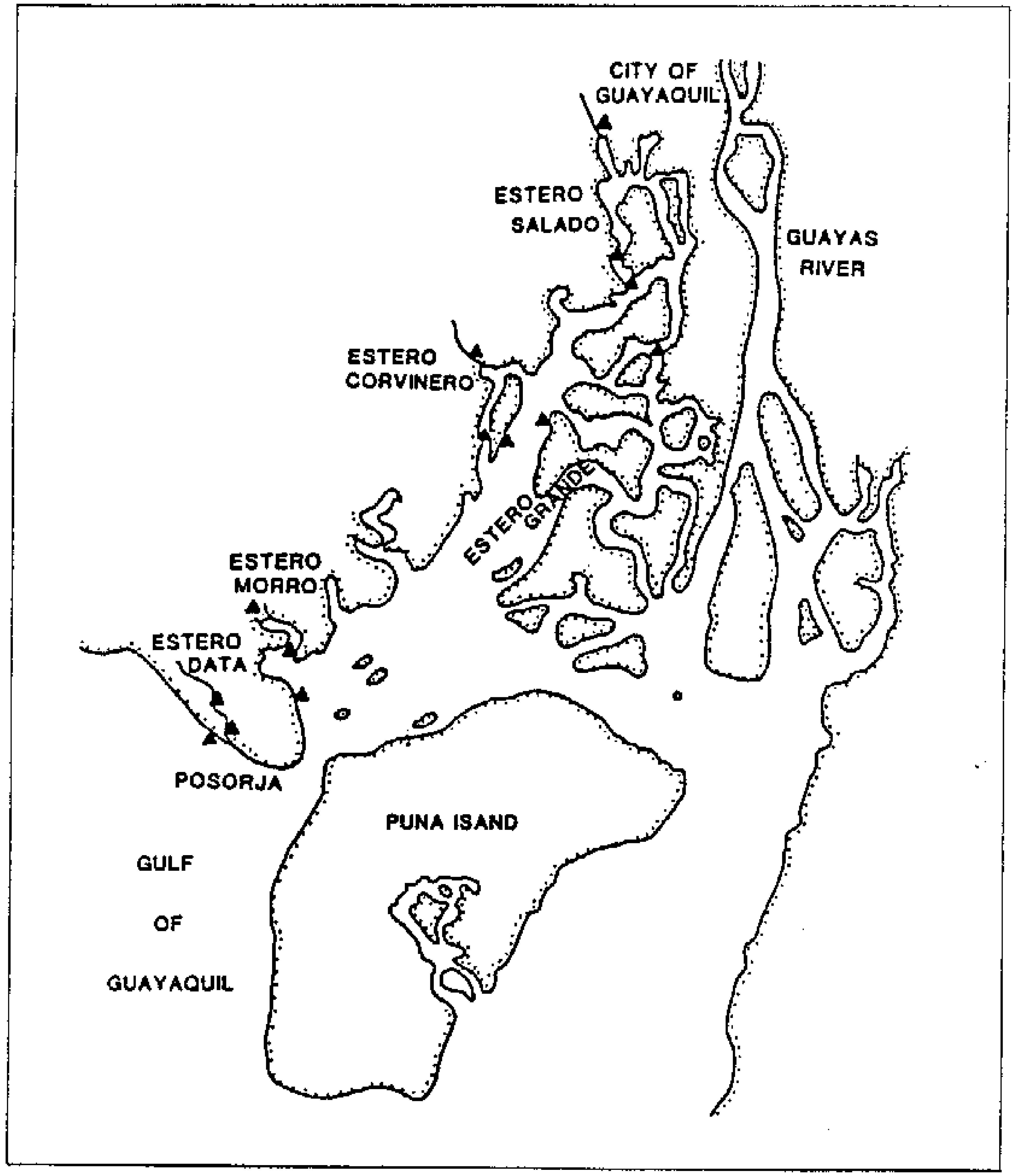


Figure 2. Mean temperatures and salinities, 1985-86.

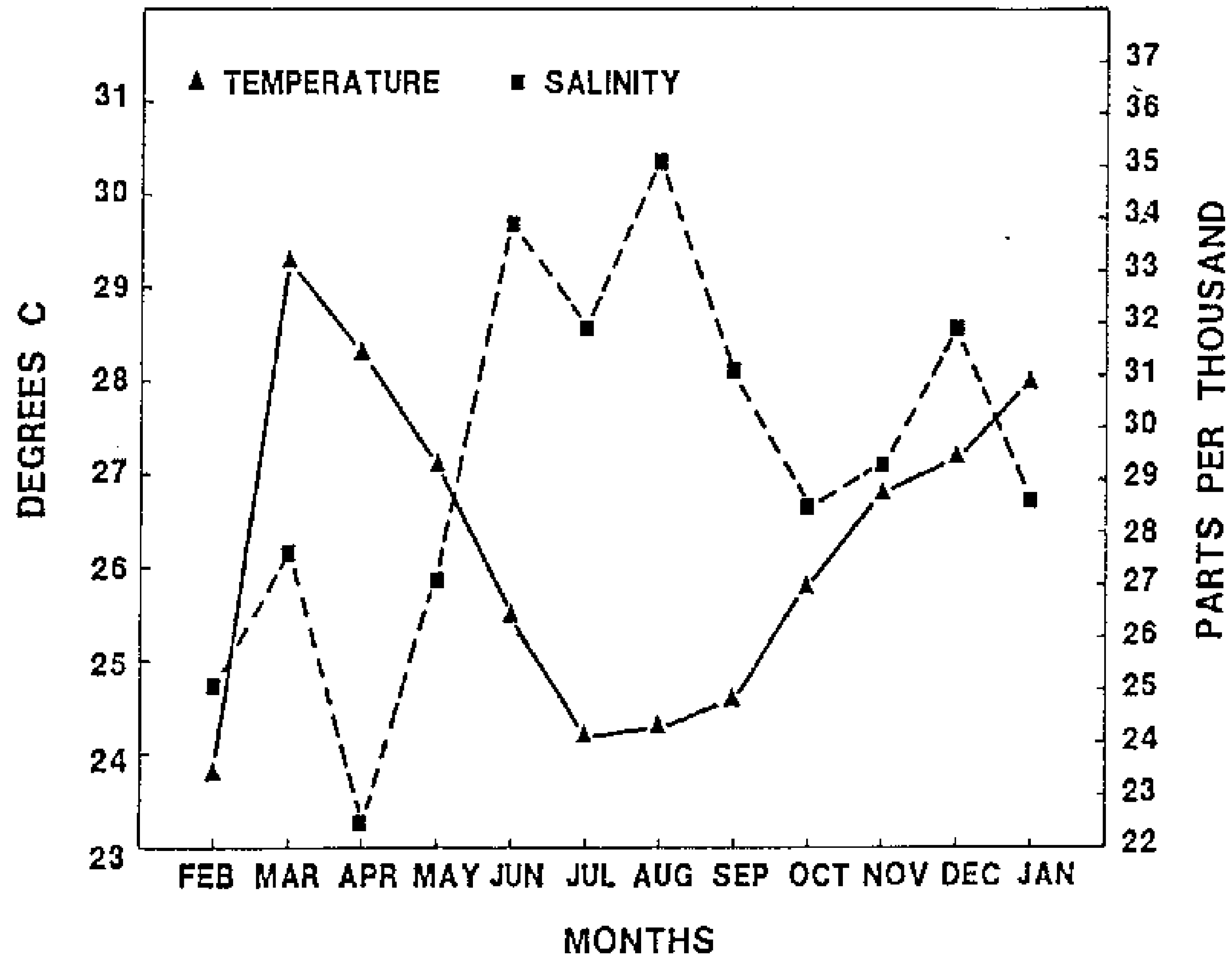


Figure 3. Mean rainfall.

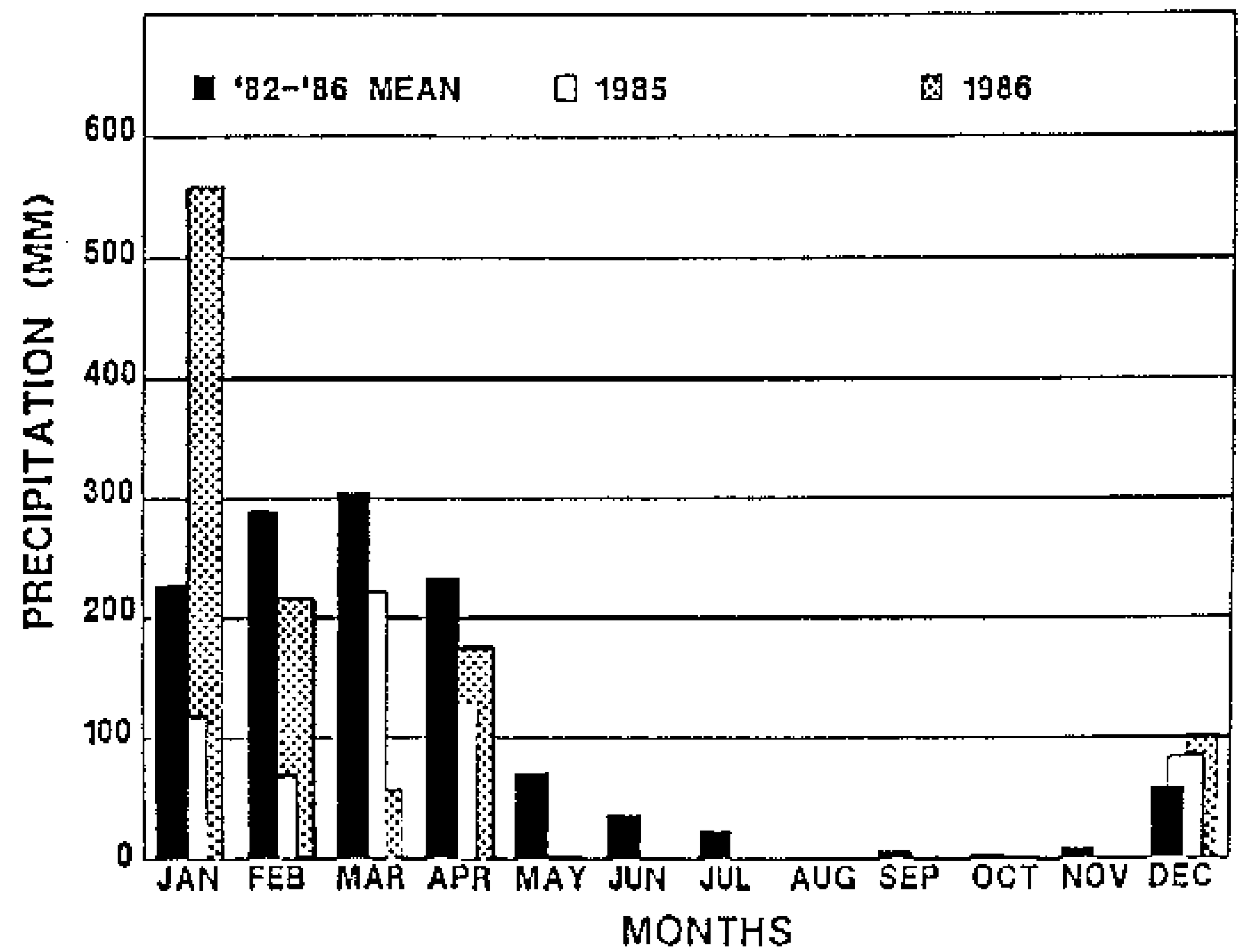


Figure 4. Shrimp abundance between esteros.

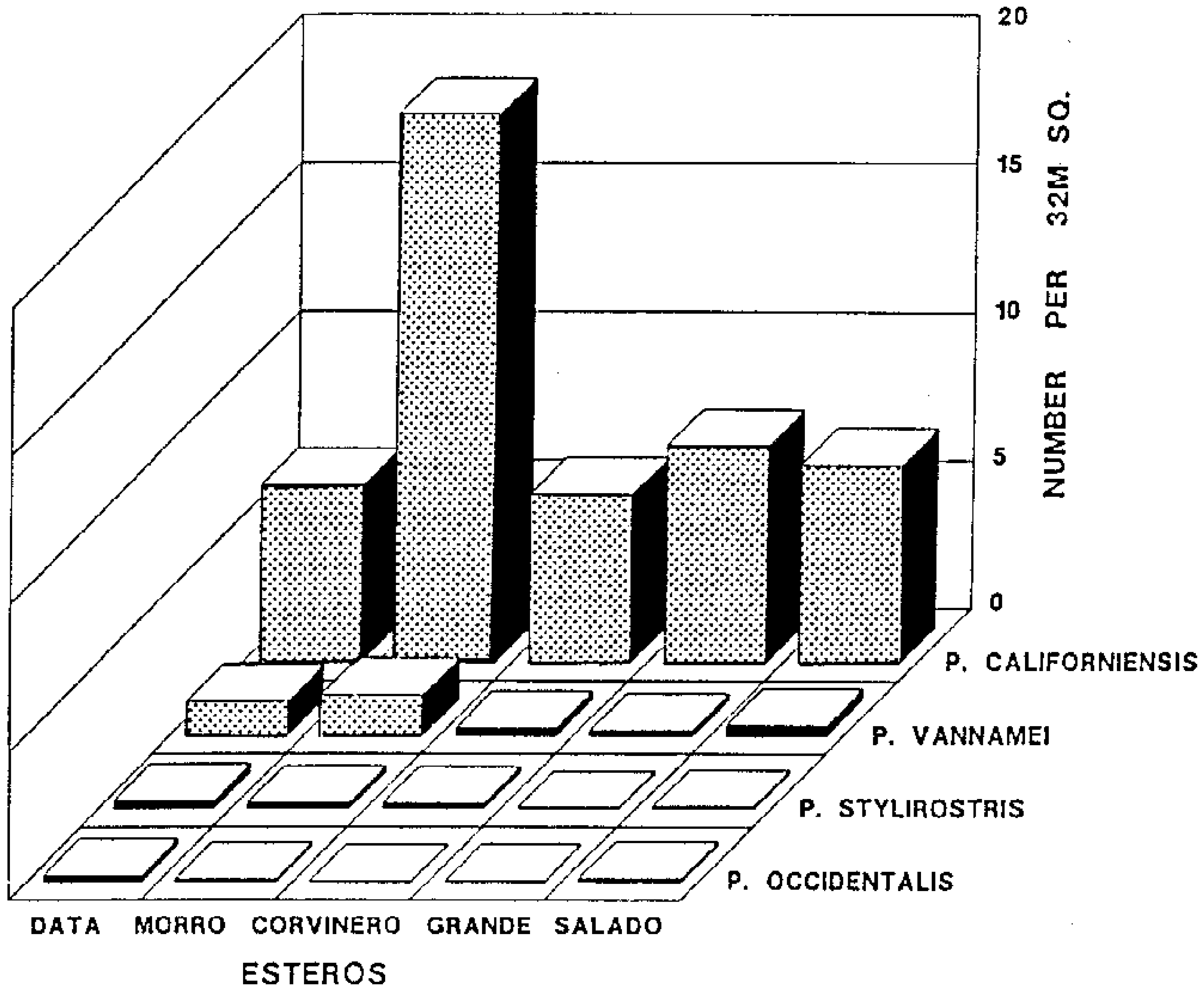


Figure 5. Temporal abundance patterns.

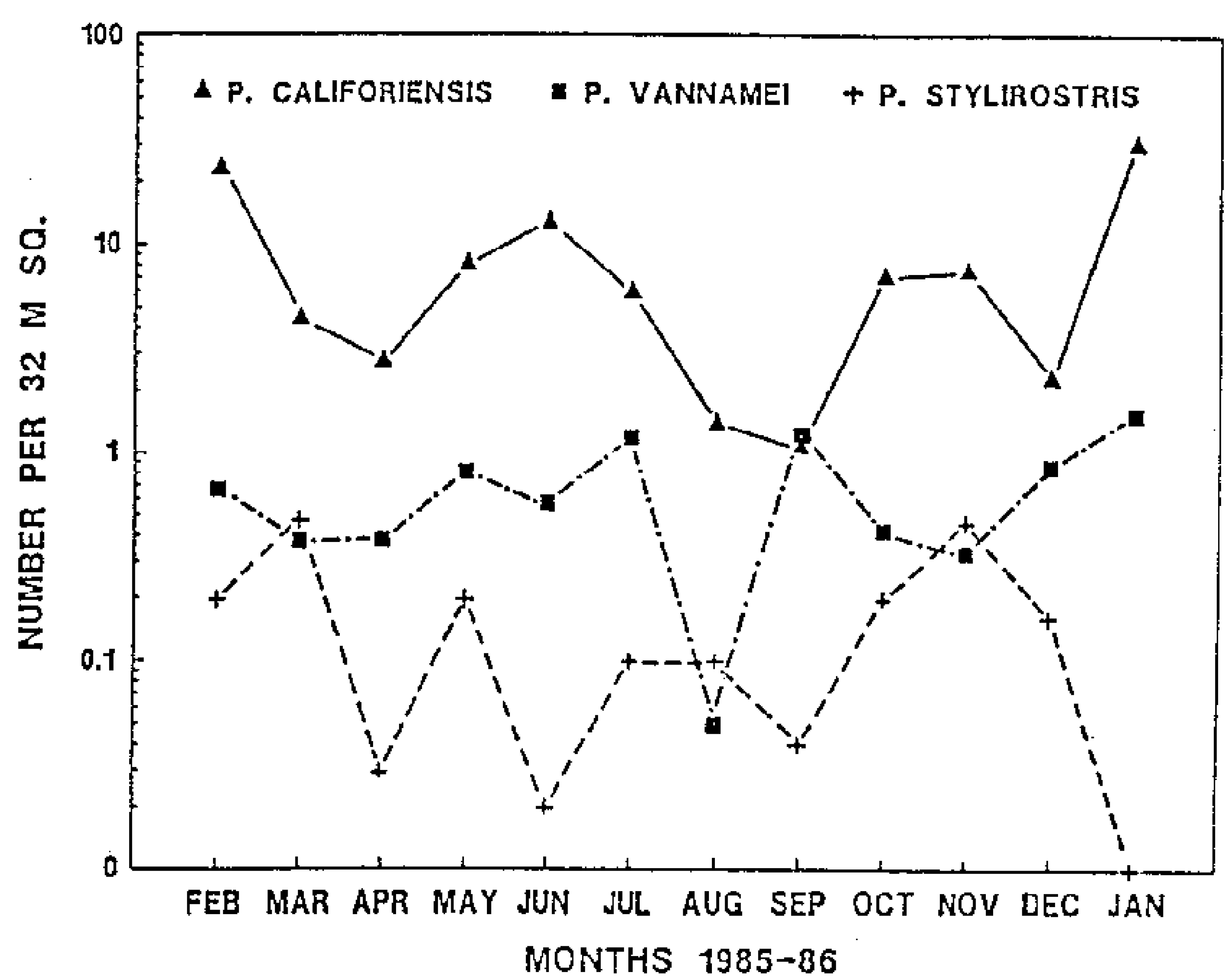
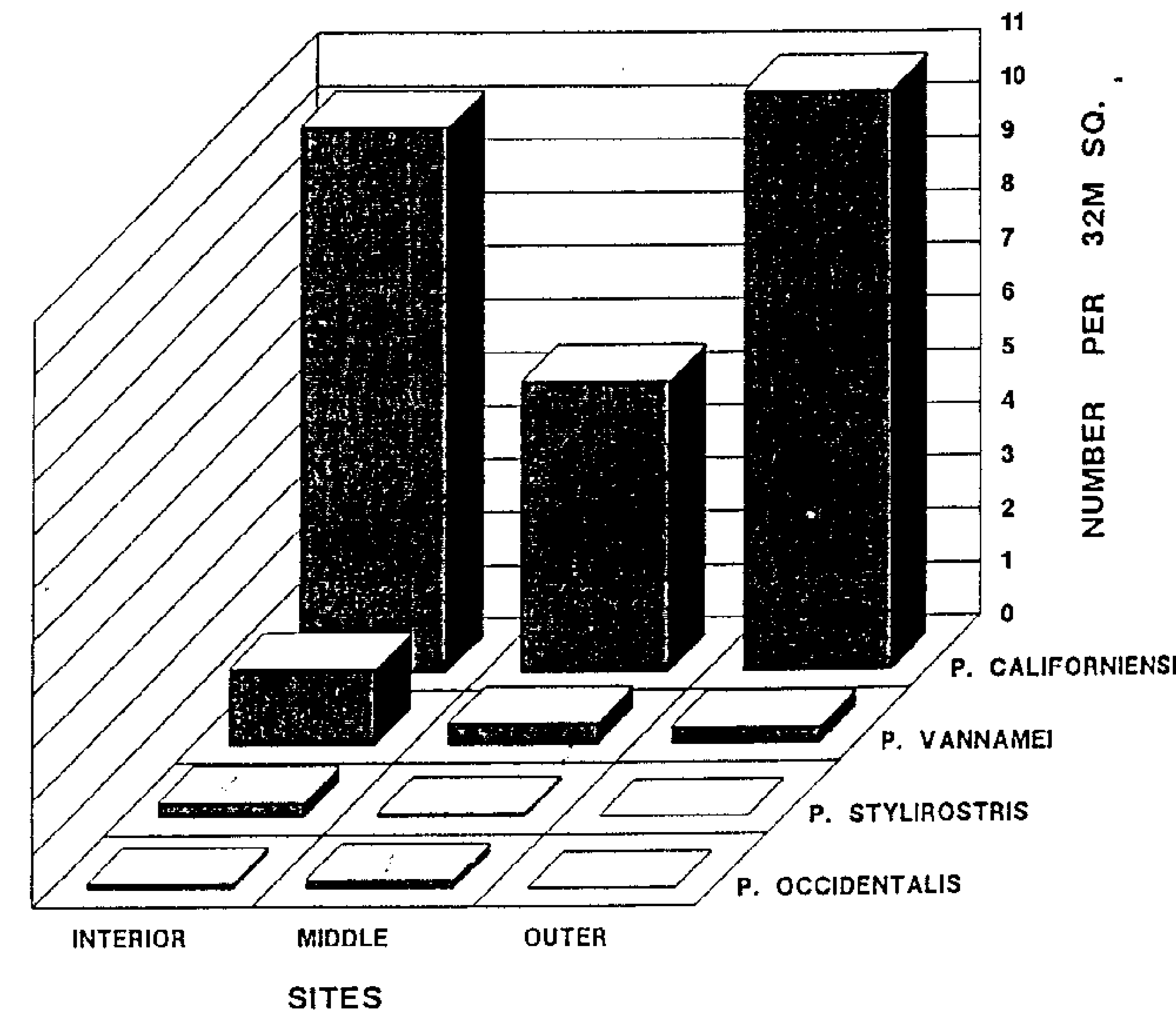


Figure 6. Shrimp Abundances Within Esteros



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